US010116303B2

(12) **United States Patent**
Mao et al.

(10) **Patent No.:** US 10,116,303 B2
(45) **Date of Patent:** Oct. 30, 2018

(54) **PARALLEL DEVICES HAVING BALANCED SWITCHING CURRENT AND POWER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 61 days.

(21) Appl. No.: **15/201,002**

(22) Filed: **Jul. 1, 2016**

(65) **Prior Publication Data**

US 2018/0006644 A1   Jan. 4, 2018

(51) **Int. Cl.**
H03B 1/00   (2006.01)
*H03K 3/00*   (2006.01)
H03K 17/687   (2006.01)

(52) **U.S. Cl.**
CPC **H03K 17/6871** (2013.01)

(58) **Field of Classification Search**
CPC H03K 17/6871

USPC 327/108–112
See application file for complete search history.

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(57)   **ABSTRACT**

A power circuit includes a power source for providing electrical power and two driving transistors being disposed in parallel and receiving electrical power from the power source. Each of the two driving transistors includes a gate terminal, a source connection, and a kelvin source connection. The power circuit also includes a control voltage source having a first terminal and a second terminal. The control voltage source provides a control signal to the two driving transistors for determining driving currents through the two driving transistors. The first terminal is connected to the gate terminals of the two driving transistors, and the second terminal is connected to the kelvin source connections of the two driving transistors. The kelvin source connections of the two driving transistors are inductively coupled.

38 Claims, 5 Drawing Sheets
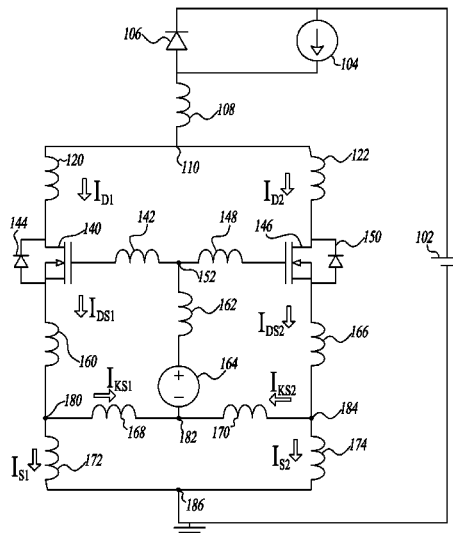
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FIG. 1

200

240   246

I_{DS1} + I_{DS2}

I_{KS1} I_{KS2}

                    264

268   270

I_{S1} 272 I_{S2} 274

FIG. 2

300

340   346

                    364

368

372   370   374

FIG. 3

400

440   446

464

468

470

472   474

FIG. 4

500

540   546

564

569

572   571   574

FIG. 5

600

640   646

669

664

672   671   674

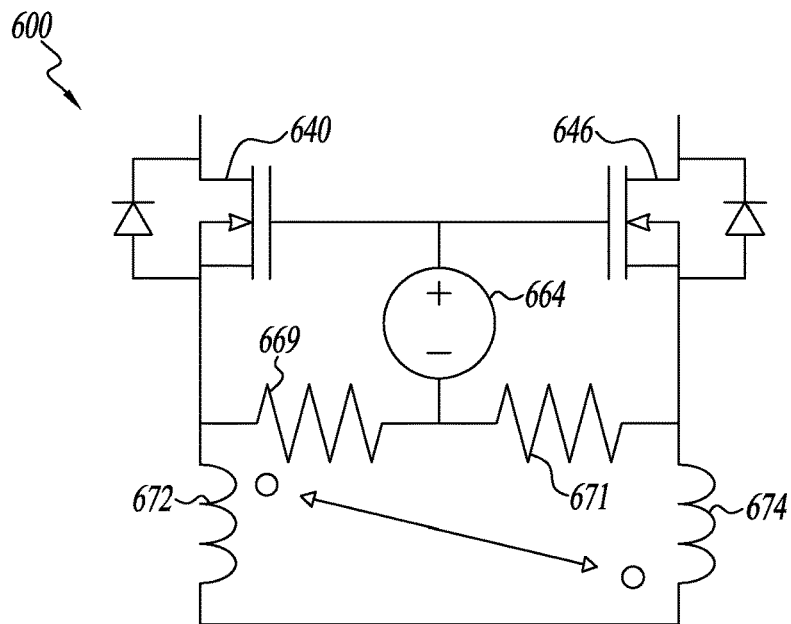*FIG. 6*
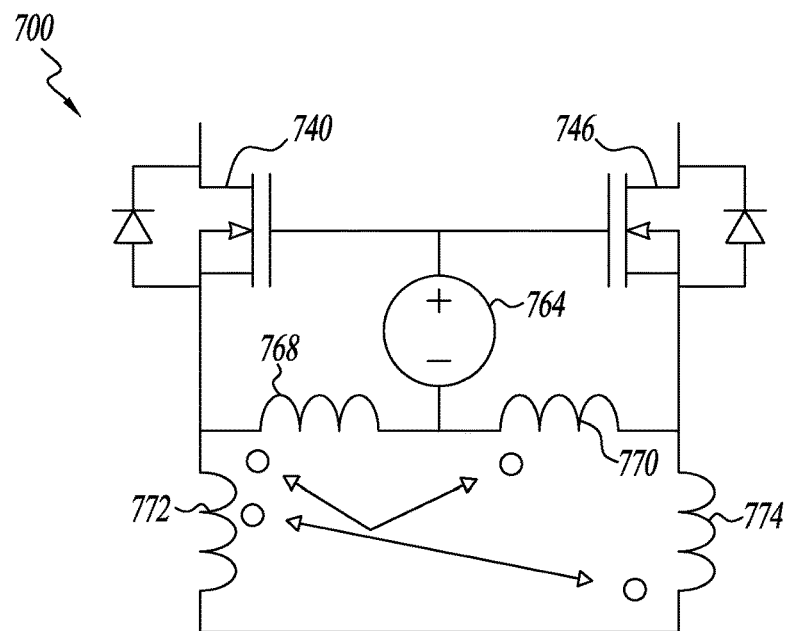
700
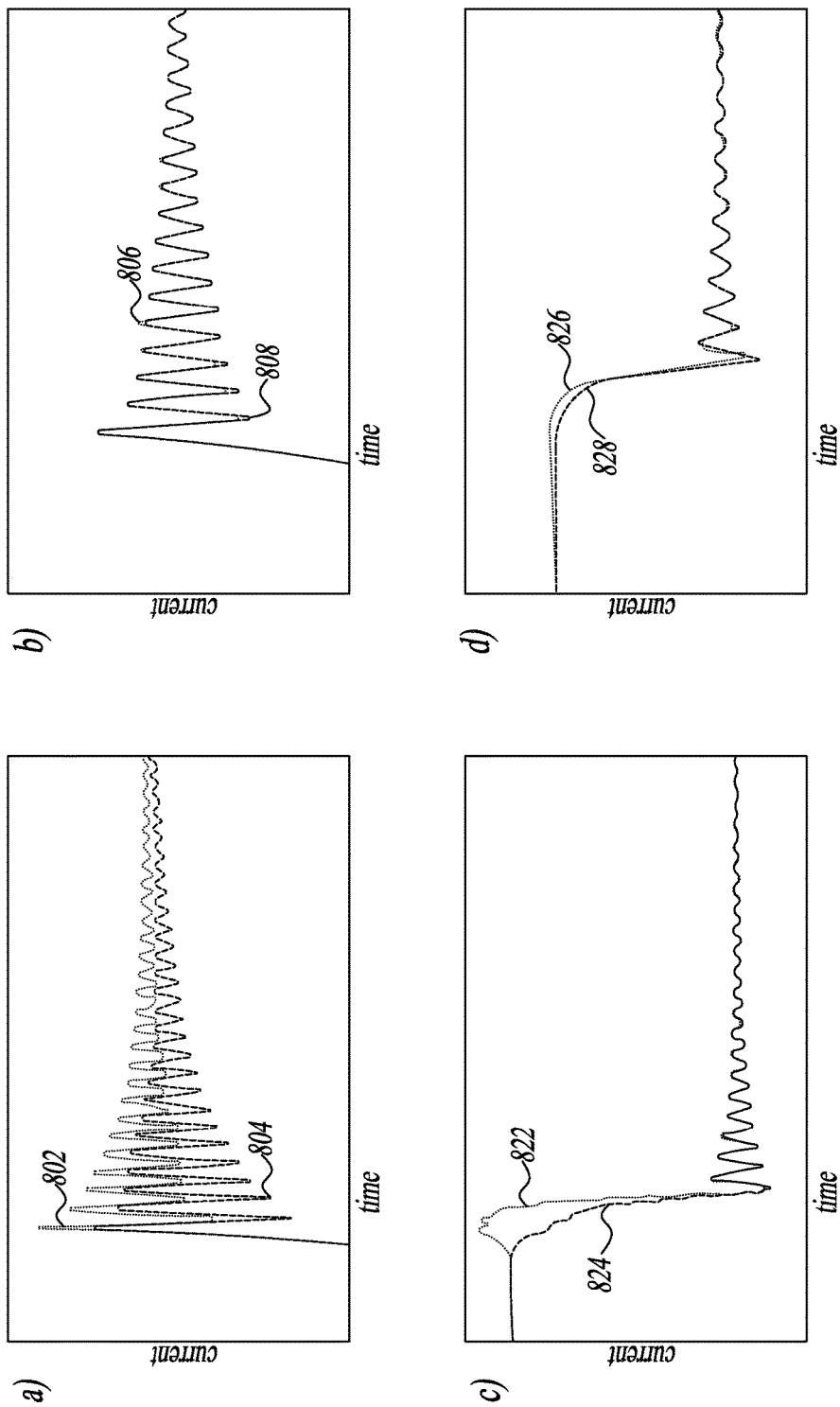
740   746

768   764

770

772   774
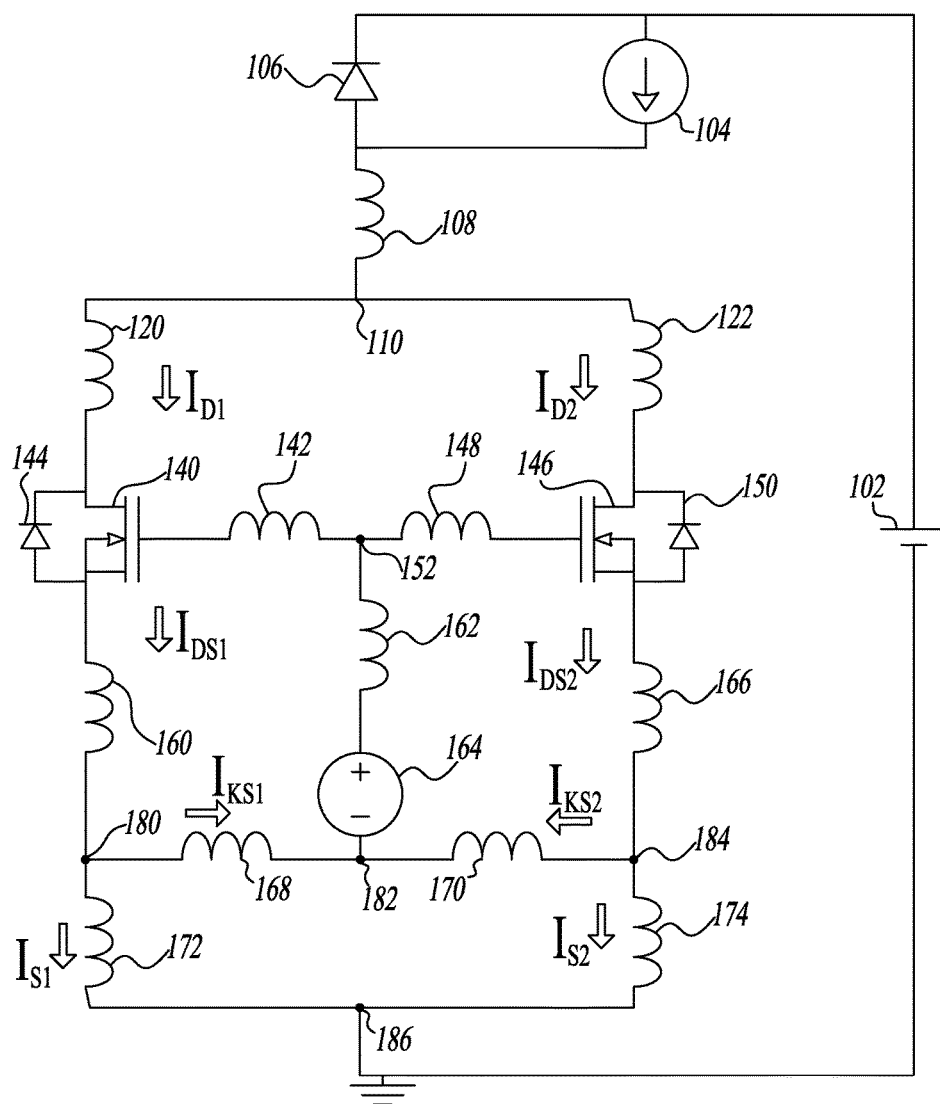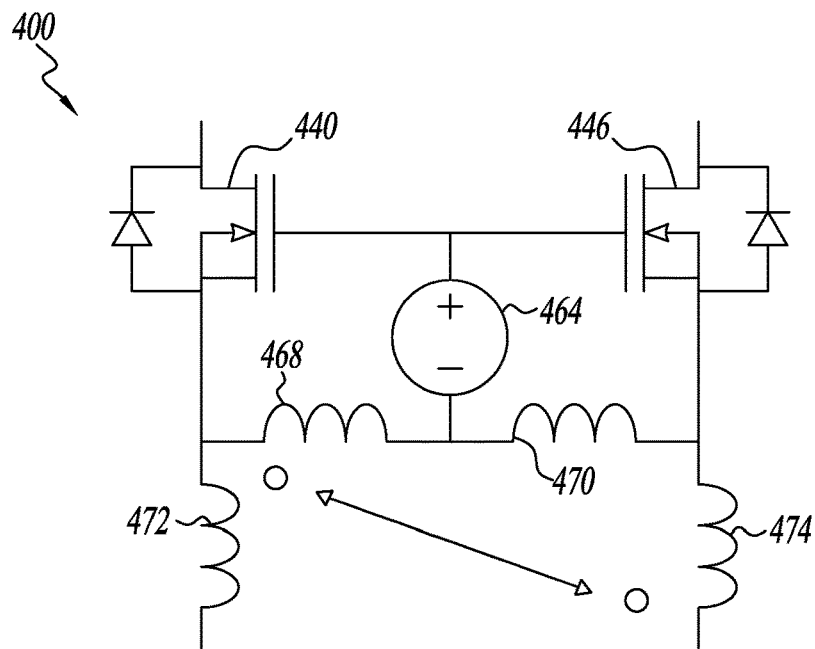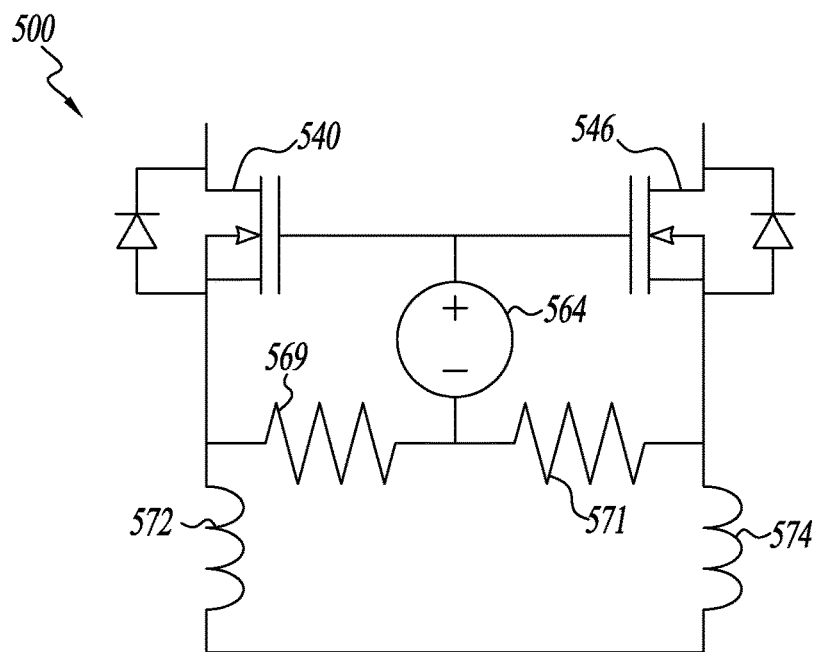
FIG. 7

FIG. 8

PARALLEL DEVICES HAVING BALANCED SWITCHING CURRENT AND POWER

BACKGROUND

Solid state power electronics have numerous industry applications such as automotive, illumination, electricity generation, and heavy machinery. These applications may expose the driving solid state power electronics to thousands of amperes of current and/or thousands of volts of voltage. Due to the large amount of driving current/voltage, the materials and designs of power electronics may differ drastically from conventional semiconductor devices. Common device structures include diode, metal-oxide-semiconductor field-effect transistor (MOSFET), bipolar junction transistor (BJT), thyristor, triac, and insulated-gate bipolar transistor (IGBT). Solid state power electronics may be built from semiconductor materials such as silicon, silicon carbide, gallium nitride, or other elemental or compound semiconductor materials.

SUMMARY

Aspects of the disclosure provide a power circuit having a power source for providing electrical power and two driving transistors being disposed in parallel and receiving electrical power from the power source. Each of the two driving transistors includes a gate terminal, a source connection, and a kelvin source connection. The power circuit also includes a control voltage source having a first terminal and a second terminal. The control voltage source provides a control signal to the two driving transistors to activate the two driving transistors. The first terminal is connected to the gate terminals of the two driving transistors, and the second terminal is connected to the kelvin source connections of the two driving transistors. The kelvin source connections of the two driving transistors are inductively coupled.

Aspects of the disclosure provide a voltage supply for providing electrical power, a current source for providing substantially constant current over a predetermined current range, a control voltage source, a first driving transistor having a first gate, a first source connection, and a first kelvin source connection, and a second driving transistor having a second gate, a second source connection, and a second kelvin source connection. The first gate and the first kelvin source connections are electrically connected to the control voltage source, and the second gate and the second kelvin source connections are electrically connected to the control voltage source. The invention includes means for inductively coupling the first and second source connections.

Aspects of the disclosure provide a circuit having a direct current voltage supply, and two driving transistors being disposed in parallel and receiving electrical power from the voltage supply. Each of the two driving transistors includes a gate terminal, a source connection, and a kelvin source connection. The circuit includes a voltage source for providing a control signal to the two driving transistors, and includes a first terminal connected to the gate terminals of the two driving transistors, and a second terminal connected to the kelvin source connections of the two driving transistors. The inductance values of the source connections are configured to improve current balancing of the two driving transistors.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an embodiment of a power circuit having balanced parallel devices.

FIG. 2 illustrates an embodiment of the power circuit having balanced parallel devices, where the kelvin source inductors and source inductors are in a parallel configuration.

FIG. 3, illustrates another embodiment of the power circuit having balanced parallel devices, where the source inductors are in a parallel configuration with the coupled kelvin source inductors.

FIG. 4, illustrates yet another embodiment of the power circuit having balanced parallel devices, where the kelvin source inductors are in a parallel configuration with the coupled source inductors.

FIG. 5 illustrates still another embodiment of the power circuit having balanced parallel devices, where the kelvin source resistors and source inductors are in a parallel configuration.

FIG. 6, illustrates an embodiment of the power circuit having balanced parallel devices, where the kelvin source resistors are in a parallel configuration with the coupled source inductors.

FIG. 7 illustrates another exemplary embodiment of the power circuit having balanced parallel devices, where the parasitic coupled kelvin source inductors and coupled source inductors are in a parallel configuration.

FIGS. 8a-d illustrate turn-on (a and b) and turn-off (c and d) behaviors of power circuits with (b and d) and without (a and c) balanced parallel devices.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 shows a power circuit 100 having parallel devices. In some implementations, the power circuit 100 includes a voltage source 102 and a current source 104. The voltage 102 supplies electrical energy to the power circuit 100, while the current source 104 provides a substantially constant supply current I_D toward a node 110. A reverse diode 106 provides a current circulating path to emulate load current during turn-off. The supply current I_D may flow from the current source 104 toward a node 110 through a parasitic input inductor 108.

At the node 110, in certain embodiments, the supply current I_D may be divided into drain currents I_{D1}, I_{D2}, which may be the same or different. Each drain current I_{D1}, I_{D2} flows through transistor drain inductors 120, 122, respectively, into parallel driving transistors 140, 146. While the driving transistors 140, 146 are shown as metal-oxide-semiconductor field-effect transistors (MOSFETs) in FIG. 1, other device structures are possible, such as bipolar junction transistor (BJT), thyristor, triac, high-electron-mobility transistor, junction field effect transistor, metal-semiconductor field effect transistor, and insulated-gate bipolar transistor (IGBT). In an exemplary embodiment, the driving transistors 140, 146 are parallel Silicon Carbide (SiC) MOSFETs. Alternatively, the driving transistors 140, 146 may be built from semiconductor materials such as silicon, germanium, gallium nitride, or other elemental or compound semiconductor materials. The driving transistors 140, 146 may be n-type MOSFETs.

In some embodiments, the driving transistors 140, 146 may be disposed on two separate semiconductor substrates. The voltage source 102, a control voltage source 164, and the driving transistors 140, 146 disposed on separate circuit boards and interconnected with wires. Alternatively, the voltage source 102 and the control voltage source 164 may share a single circuit board. The control voltage source 164 may provide a control signal to the driving transistors 140, 146 to activate the driving transistors 140, 146.

In some implementations, the driving transistor **140** may include an intrinsic diode **144**, which is a parasitic circuit element formed between the drain terminal and body or source of the driving transistor **140**. Similarly, the driving transistor **146** may include an intrinsic diode **150** formed between the drain terminal and body or source of the driving transistor **146**.

In exemplary embodiments, the control voltage source **164** is connected to the gate of the driving transistor **140** via an input inductor **162** and a gate inductor **142**. Similarly, the control voltage source **164** is connected to the gate of the driving transistor **146** via the input inductor **162** and a gate inductor **148**. The gate inductors **142**, **148** and the input inductor **162** converge at a node **152**.

In certain implementations, a common source current I_{DS1} flows through a common source inductor **160** toward a node **180**. At the node **180**, the common source current I_{DS1} splits into a source current I_{S1} and a kelvin source current I_{KS1}. The source current I_{S1} flows through a source inductor **172** toward a node **186**, and the kelvin source current I_{ks1} flows through a kelvin source inductor **168** toward a node **182**. Similarly, a common source current I_{DS2} flows through a common source inductor **166** toward a node **184**. At the node **184**, the common source current I_{DS2} splits into a source current I_{S2} and a kelvin source current I_{KS2}. The source current I_{S2} flows through a source inductor **174** toward the node **186**, and the kelvin source current I_{KS2} flows through a kelvin source inductor **170** toward the node **182**. The node **186** may be grounded. The common source current I_{DS1} may be similar in magnitude as the drain current I_{D1}, and the common source current I_{DS2} may be similar in magnitude as the drain current I_{D2}.

In some embodiments, some of the inductors in the power circuit **100** may be parasitic inductors. Parasitic inductors may be metallic wires exhibiting inductance in the presence of electrical currents. Some of the inductors in the power circuit **100** may be non-parasitic inductors configured to exhibit a certain inductance value. An exemplary non-parasitic inductor may be an air core inductor or a ferromagnetic core inductor. The inductance value of an inductor may be tuned by changing the number of coils or the ferromagnetic material of the core. Exemplary ferromagnetic materials include elements such as Cobalt, Iron, and Nickel, compounds such as Iron(III) Oxide and Chromium (IV) Oxide, and alloys such as nickel-iron and Heusler alloy. Other ferromagnetic materials may also be used to alter the inductance value of an inductor.

FIGS. **2-7** illustrate some embodiments of the power circuits for balancing parallel device switching current and power. Certain circuit elements have been removed to simplify the figures. Referring to FIG. **2**, the power circuit **200** includes driving transistors **240**, **246**, a control voltage source **264**, kelvin source inductors **268**, **270**, and source inductors **272**, **274**. A common source current I_{DS1} is split into a source current I_{S1} and a kelvin source current I_{ks1}, and a common source current I_{DS2} is split into a source current I_{S2} and a kelvin source current I_{ks2}. A difference in current flowing through the driving transistors **240**, **246** may be approximated as:

$$I_{DS1}-I_{DS2}=(I_{S1}-I_{S2})+(I_{KS1}-I_{KS2}),$$

which can be expressed as:

$$v_{DS1} - v_{DS2} = v_{S2} - v_{S1} = L_S\left(\frac{dI_{S2}}{dt} - \frac{dI_{S1}}{dt}\right) = L_S\left(\frac{dI_{KS2}}{dt} - \frac{dI_{KS1}}{dt}\right),$$

where v_{DS1} and v_{DS2} are drain-to-source voltages across the driving transistors **240**, **246**, v_{S1} and v_{S2} are the voltages at source terminals of the transistors **240**, **246**, and L_S is an inductance value of the source inductors **272**, **274**. The transistors common source current I_{DS1} and I_{DS2} can be approximately as:

$$I_{DS1}=g_{FS}(v_{GS1}-V_{th1}),\text{ and}$$

$$I_{DS2}=g_{FS}(v_{GS2}-V_{th2}),$$

where g_{FS} is the transconductance of the driving transistors **240**, **246**, v_{GS1} and v_{GS2} are the gate-to-source voltages, and V_{th1} and V_{th2} are the threshold voltages. From the above equation, the difference between the drain-to-source voltages may be expressed as:

$$v_{DS1}-v_{DS2}=v_{S2}-v_{S1}=v_{GS1}-v_{GS2}=V_{th1}-V_{th2}.$$

The difference between the source currents I_{S1} and I_{S2} is:

$$I_{S1} - I_{S2} = \frac{V_{th2} - V_{th1}}{L_S}t$$

and the difference between the kelvin source currents I_{KS1} and I_{KS2} is:

$$I_{KS1} - I_{KS2} = \frac{V_{th2} - V_{th1}}{L_{KS}}t,$$

where L_{KS} is an inductance value of the kelvin source inductors **268**, **270**. The difference in common source currents I_{DS1} and I_{DS2} may be expressed as a function of the threshold voltages, the kelvin source inductors **268**, **270**, and the source inductors **272**, **274**:

$$I_{DS1} - I_{DS2} = (I_{S1} - I_{S2}) + (I_{KS1} - I_{KS2}) = \frac{V_{th2} - V_{th1}}{L_S // L_{KS}}t.$$

Still referring to FIG. **2**, in some embodiments, the difference in the common source currents I_{DS1}, I_{DS2} may be represented by the expression

$$\frac{V_{th2} - V_{th1}}{L_S // L_{KS}}t,$$

which may be reduced by reducing the difference in threshold voltages V_{th1} and V_{th2} or maximizing both L_S and L_{KS}. A reduction in the difference in the common source currents I_{DS1}, I_{DS2} may improve the balance of switching current and power of the parallel driving transistors **240**, **246**.

In some embodiments, two transistors with significantly different threshold voltages may be utilized as parallel driving transistors. A screening process to pre-select transistors with similar threshold voltage values may be simplified or even eliminated by balancing the currents of parallel driving transistors using appropriate inductance values.

Referring now to FIG. **3**, which shows an exemplary embodiment of a power circuit **300** having balanced parallel devices. The power circuit **300** includes driving transistors **340**, **346**, a control voltage source **364**, kelvin source inductors **368**, **370**, and source inductors **372**, **374**. In certain implementations, the kelvin source inductors **368**, **370** may

be magnetically coupled. Various methods of magnetic coupling are possible. The kelvin source inductor **368** may be disposed near the kelvin source inductor **370**. Alternatively, the inductance values of the kelvin source inductors **368**, **370** may be amplified by adding additional inductors in series with the kelvin source inductors **368**, **370** or by adding ferromagnetic materials between the kelvin source inductors **368**, **370**. Other methods are possible.

Still referring to FIG. **3**, in some implementations, the difference in the common source currents (not shown) may be represented by the expression

$$\frac{V_{th2} - V_{th1}}{L_S \,/\!/\, (L_{KS} + M)} t,$$

where V_{th1} and V_{th2} are threshold voltages of driving transistors **340**, **346**, L_S is an inductance value of the source inductors **372**, **374**, L_{KS} is an inductance value of the kelvin source inductors **368**, **370**, t is time, and M is a magnetic coupling term. M, for example, may range from $-L_{KS}{<}0{<}L_{KS}$. The difference in common source currents may be minimized by reducing the difference in threshold voltages V_{th1} and V_{th2} or maximizing both L_S and (L_{KS}+M). A reduction in the difference in the common source currents may improve the balance of switching current and power of the parallel driving transistors **340**, **346**.

Referring now to FIG. **4**, which shows another exemplary embodiment of a power circuit **400** having balanced parallel devices. The power circuit **400** includes driving transistors **440**, **446**, a control voltage source **464**, kelvin source inductors **468**, **470**, and source inductors **472**, **474**. In certain implementations, the source inductors **472**, **474** may be magnetically coupled. Various methods of magnetic coupling are possible. The source inductor **472** may be disposed near the source inductor **474**. Alternatively, the inductance values of the source inductors **472**, **474** may be amplified by adding additional inductors in series with the source inductors **472**, **474** or by adding ferromagnetic materials between the source inductors **472**, **474**. Other methods are possible.

Still referring to FIG. **4**, in some implementations, the difference in the common source currents (not shown) may be represented by the expression

$$\frac{V_{th2} - V_{th1}}{(L_S + M) \,/\!/\, L_{KS}} t,$$

where V_{th1} and V_{th2} are threshold voltages of driving transistors **440**, **446**, L_S is an inductance value of the source inductors **472**, **474**, L_{KS} is an inductance value of the kelvin source inductors **468**, **470**, t is time, and M is a magnetic coupling term. M, for example, may range from $-L_S{<}0{<}L_S$. The difference in common source currents may be minimized by reducing the difference in threshold voltages V_{th1} and V_{th2} or maximizing both (L_S+M) and L_{KS}. A reduction in the difference in the common source currents may improve the balance of switching current and power of the parallel driving transistors **440**, **446**.

Referring now to FIG. **5**, which shows a further exemplary embodiment of a power circuit **500** having balanced parallel devices. The power circuit **500** includes driving transistors **540**, **546**, a control voltage source **564**, kelvin source resistors **569**, **571**, and source inductors **572**, **574**. In

certain implementations, the difference in the common source currents (not shown) may be represented by the expression

$$\frac{V_{th2} - V_{th1}}{R_{KS}} + \frac{V_{th2} - V_{th1}}{L_S} t,$$

where V_{th1} and V_{th2} are threshold voltages of driving transistors **540**, **546**, L_S is an inductance value of the source inductors **572**, **574**, R_{KS} is a resistance value of the kelvin source resistors **569**, **571**, and t is time. The difference in common source currents may be minimized by reducing the difference in threshold voltages V_{th1} and V_{th2} or maximizing both R_{KS} and L_S. The kelvin source resistors **569**, **571** may be parasitic resistors, externally added resistors, or a combination of both. The resistance values of the kelvin source resistors **569**, **571** may be increased, for example, by adding a ceramic resistor, a printed carbon resistor, a metal resistor, an alloy resistor, a metal-oxide resistor, or semiconductor resistor to the kelvin source resistors **569**, **571**. A reduction in the difference in the common source currents may improve the balance of switching current and power of the parallel driving transistors **540**, **546**.

Referring now to FIG. **6**, which shows yet another exemplary embodiment of a power circuit **600** having balanced parallel devices. The power circuit **600** includes driving transistors **640**, **646**, a control voltage source **664**, kelvin source resistors **669**, **671**, and source inductors **672**, **674**. In certain implementations, the source inductors **672**, **674** may be magnetically coupled. Various methods of magnetic coupling are possible. The source inductor **672** may be disposed near the source inductor **674**. Alternatively, the inductance value of the source inductors **672**, **674** may be amplified by adding additional inductors in series with the source inductors **672**, **674** or by adding ferromagnetic materials between the source inductors **672**, **674**. Other methods are possible.

Still referring to FIG. **6**, in some implementations, the difference in the common source currents (not shown) may be represented by the expression

$$\frac{V_{th2} - V_{th1}}{R_{KS}} + \frac{V_{th2} - V_{th1}}{L_S + M} t,$$

where V_{th1} and V_{th2} are threshold voltages of driving transistors **640**, **646**, L_S is an inductance value of the source inductors **672**, **674**, R_{KS} is a resistance value of the kelvin source resistors **669**, **671**, t is time, and M is a magnetic coupling term. M, for example, may range from $-L_S{<}0{<}L_S$. The difference in common source currents may be minimized by reducing the difference in threshold voltages V_{th1} and V_{th2} or maximizing both (L_S+M) and R_{KS}. The resistance values of the kelvin source resistors **669**, **671** may be increased, for example, by adding a ceramic resistor, a printed carbon resistor, a metal resistor, an alloy resistor, a metal-oxide resistor, or semiconductor resistor to the kelvin source resistors **669**, **671**. A reduction in the difference in the common source currents may improve the balance of switching current and power of the parallel driving transistors **640**, **646**.

Referring now to FIG. **7**, which shows an exemplary embodiment of a power circuit **700** having balanced parallel devices. The power circuit **700** includes driving transistors **740**, **746**, a control voltage source **764**, kelvin source induc-

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tors **768, 770**, and source inductors **772, 774**. In certain implementations, the source inductors **772, 774** may be magnetically coupled and the kelvin source inductors **768, 770** may be magnetically coupled. Various methods of magnetic coupling are possible. The source inductor **772** may be disposed near the source inductor **774**. Alternatively, the inductance values of the source inductors **772, 774** may be amplified by adding additional inductors in series with the source inductors **772, 774** or by adding ferromagnetic materials between the source inductors **772, 774**. Similarly, the kelvin source inductor **768** may be disposed near the source inductor **770**. Alternatively, the inductance values of the kelvin source inductors **768, 770** may be amplified by adding additional inductors in series with the kelvin source inductors **768, 770** or by adding ferromagnetic materials between the kelvin source inductors **768, 770**. Other methods are possible.

Still referring to FIG. **7**, in some implementations, the difference in the common source currents (not shown) may be represented by the expression

$$\frac{V_{th2} - V_{th1}}{(L_S + M_S) \, / / \, (L_{KS} + M_{KS})} t,$$

where V_{th1} and V_{th2} are threshold voltages of driving transistors **740, 746**, L_S is an inductance value of the source inductors **772, 774**, L_{KS} is an inductance value of the kelvin source inductors **768, 770**, t is time, M_S is a source magnetic coupling term, and M_{KS} is a kelvin source magnetic coupling term. M_S, for example, may range from $-L_S < 0 < L_S$ and M_{KS} may range from $-L_{KS} < 0 < L_{KS}$. The difference in common source currents may be minimized by reducing the difference in threshold voltages V_{th1} and V_{th2} or maximizing both $(L_S + M)$ and $(L_{KS} + M)$. A reduction in the difference in common source currents may improve the balance of switching current and power of the parallel driving transistors **740, 746**.

While FIGS. **1-7** illustrate embodiments of power circuits having two parallel driving transistors, more parallel driving transistors may be included in the power circuits. The methods described above for balancing parallel transistors switching current are similarly applicable to power circuits having more than two parallel driving transistors.

Referring now to FIGS. **8a-d**, which illustrate turn-on (**8a** and **8b**) and turn-off (**8c** and **8d**) behaviors of power circuits with (**8b** and **8d**) and without (**8a** and **8c**) balanced parallel devices. In exemplary implementations, curves **802, 804** in FIG. **8a** may represent turn-on behaviors of unbalanced parallel transistors. Curves **806, 808** in FIG. **8b** show turn-on behaviors of balanced parallel transistors. Turning to FIG. **8c**, curves **822, 824** may represent turn-off behaviors of unbalanced parallel transistors. In FIG. **8d**, curves **826, 828** show turn-off behaviors of balanced parallel transistors.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of this disclosure. For example, preferable results may be achieved if the steps of the disclosed techniques were performed in a different sequence, if components in the disclosed systems were combined in a different manner, or if the components were replaced or supplemented by other components. The functions, processes and algorithms described herein may be performed in hardware or software executed by hardware, including computer processors and/ or programmable circuits configured to execute program

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code and/or computer instructions to execute the functions, processes and algorithms described herein. Additionally, some implementations may be performed on modules or hardware not identical to those described. Accordingly, other implementations are within the scope that may be claimed.

The invention claimed is:

1. A system comprising:
   a power source that provides electrical power;
   two driving transistors disposed in parallel and receiving electrical power from the power source, wherein each of the two driving transistors includes a gate terminal, a source connection, and a kelvin source connection; and
   a control voltage source having a first terminal and a second terminal, wherein:
      the control voltage source provides a control signal to the two driving transistors to activate the two driving transistors,
      the first terminal is connected to the gate terminal of a first of the two driving transistors via a common inductor and a first inductor,
      the first terminal is connected to the gate terminal of a second of the two driving transistors via the common inductor and a second inductor, and
      the second terminal is connected to the kelvin source connections of the two driving transistors;
   wherein the kelvin source connections of the two driving transistors are inductively coupled.

2. The circuit of claim **1**, wherein the kelvin source connections are inductively coupled by inserting a coil inductor in series with at least one of the kelvin source connections.

3. The circuit of claim **1**, further comprising a ferromagnetic material disposed in between the kelvin source connections.

4. The circuit of claim **1**, wherein the source connections of the two driving transistors are inductively coupled.

5. The circuit of claim **4**, wherein the source connections are inductively coupled by inserting a coil inductor in series with at least one of the source connections.

6. The circuit of claim **4**, further comprising a ferromagnetic material disposed in between the source connections.

7. A power circuit, comprising:
   a voltage supply that provides electrical power;
   a current source that provides substantially constant current over a predetermined current range;
   a control voltage source;
   a first driving transistor having a first gate, a first source connection, and a first kelvin source connection, wherein the first gate and the first kelvin source connection are electrically connected to the control voltage source;
   a second driving transistor having a second gate, a second source connection, and a second kelvin source connection, wherein the second gate and the second kelvin source connection are electrically connected to the control voltage source; and
   an inductive coupling circuit to inductively couple the first and second source connections,
   wherein the control voltage source includes at least a first terminal coupled to the first gate via a common inductor and a first inductor, and coupled to the second gate via the common inductor and a second inductor.

8. The power circuit of claim **7**, further comprising means for inductively coupling the first and second kelvin source connections.

9. The power circuit of claim 7, wherein the means for inductively coupling the first and second source connections includes a coil inductor disposed in series with at least one of the first or second source connections.

10. The power circuit of claim 7, further comprising a kelvin source resistor disposed in series with at least one of the first or second kelvin connection.

11. The power circuit of claim 10, wherein the kelvin source resistor is selected from the group consisting of a ceramic resistor, a printed carbon resistor, a metal resistor, an alloy resistor, a metal-oxide resistor, or semiconductor resistor.

12. The power circuit of claim 7, wherein the first and second driving transistors are silicon carbide transistors.

13. The power circuit of claim 7, wherein the first and second driving transistors are disposed on at least two semiconductor substrates.

14. A circuit comprising
a direct current voltage supply;
two driving transistors disposed in parallel and receiving electrical power from the voltage supply, each of the two driving transistors includes a gate terminal, a source connection, and a kelvin source connection; and
a voltage source that provides a control signal to the two driving transistors, including:
a first terminal connected to the gate terminal of a first one of the two driving transistors via a common inductor and a first inductor,
the first terminal is connected to the gate terminal of a second of the two driving transistors via the common inductor and a second inductor, and
a second terminal connected to the kelvin source connections of the two driving transistors;
wherein inductances of the source connections are configured to improve current balancing of the two driving transistors.

15. The circuit of claim 14, wherein inductances of the kelvin source connections are configured to improve current balancing of the two driving transistors.

16. The circuit of claim 14, wherein resistances of the kelvin source connections are configured to improve the current balancing of the two driving transistors.

17. The circuit of claim 14, further comprising a ferromagnetic material disposed in between at least a portion of the source connections.

18. The circuit of claim 14, further comprising an external inductor added to at least one of the source connections.

19. The circuit of claim 14, wherein the two driving transistors are fabricated on two separate silicon carbide substrates.

20. A circuit for driving parallel transistors, comprising
a voltage supply;
at least two power transistors disposed in parallel and receiving electrical energy from the voltage supply, each of the at least two power transistors includes a gate terminal, a source connection, and a kelvin source connection; and
a voltage source that controls an operation of the at least two power transistors, including:
a first terminal electrically coupled to the gate terminal of a first of the at least two power transistors via a common inductor and a first inductor,
the first terminal is electrically coupled to the gate terminal of a second one of the at least two power transistors via the common inductor and a second inductor, and

a second terminal electrically coupled to the kelvin source connections of the at least two power transistors;
wherein inductances of the kelvin source connections are configured to improve current balancing of the at least two power transistors.

21. The circuit of claim 20, wherein inductances of the source connections are configured to improve current balancing of the at least two power transistors.

22. The circuit of claim 20, further comprising a ferromagnetic material disposed in between at least a portion of the kelvin source connections.

23. The circuit of claim 20, further comprising an external inductor added to at least one of the kelvin source connections.

24. The circuit of claim 20, wherein the at least two power transistors are fabricated on at least two silicon carbide substrates.

25. The circuit of claim 20, wherein the kelvin source connections are inductively coupled.

26. A system comprising:
two power transistors disposed in parallel, wherein each of the two driving transistors includes a gate terminal, a source connection, and a kelvin source connection;
a power source that provides electrical energy to the two power transistors; and
a control voltage having a first terminal and a second terminal, wherein the control voltage source provides at least a control signal to the gate terminals of the two power transistors to activate the two power transistors;
wherein resistances of the kelvin source connections are configured to reduce a difference in drain currents of the two power transistors; and
wherein the first terminal of the control voltage source is connected to the gate terminal of a first of the two power transistors via a common inductor and a first inductor, and is connected to the gate of a second of the two power transistors via the common inductor and a second inductor.

27. The system of claim 26, wherein each kelvin source connection of the two power transistors includes a kelvin source resistor.

28. The system of claim 27, wherein each kelvin source resistor is from the group consisting of a ceramic resistor, a printed carbon resistor, a metal resistor, an alloy resistor, a metal-oxide resistor, or semiconductor resistor.

29. The system of claim 26, wherein at least one of the source connections includes a coil inductor.

30. The system of claim 29, further comprising a ferromagnetic material disposed within a core of the coil inductor.

31. The system of claim 26, wherein the two power transistors are silicon carbide transistors.

32. The system of claim 26, wherein the two power transistors are bipolar junction transistors.

33. A circuit, comprising:
a voltage supply that provides electrical power to the circuit;
a current source that provides substantially constant current over a predetermined current range;
a control voltage source;
a first power transistor having a first gate, a first source inductor, and a first kelvin source resistor, wherein the first gate and the first kelvin source resistor are electrically coupled to the control voltage source; and
a second power transistor having a second gate, a second source inductor, and a second kelvin source resistor,

wherein the second gate and the second kelvin source resistor are electrically coupled to the control voltage source;

wherein resistances of the first and second kelvin source resistors and inductances of the first and second source inductors are configured to reduce a difference in drain currents of the first and second power transistors, and

the control voltage source is coupled to the first gate via a common inductor and a first inductor, and is coupled to the second gate via the common inductor and a second inductor.

34. The circuit of claim **33**, wherein the first and second source inductors are magnetically coupled.

35. The circuit of claim **34**, further comprising a first ferromagnetic core disposed within the first source inductor and a second ferromagnetic core disposed within the second source inductor.

36. The circuit of claim **35**, wherein the first and second ferromagnetic cores include elemental, compound, or alloy ferromagnetic materials.

37. The circuit of claim **33**, wherein the first and second power transistors are disposed on two different silicon carbide substrates.

38. The circuit of claim **33**, wherein the first and second power transistors are metal-oxide-semiconductor field-effect transistors.

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